Development *Alternatives,* Inc.

Cassava Processing in the Chapare, Bolivia: Description of Alternatives from the Latin American Experience and Evaluation of a Factory Proposal

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Abbreviations

CIAT	Centro Internacional de Agricultura Tropical
CLAYUCA	Consorcio Latinoamericano y del Caribe de Apoyo a la Investigacion y Desarrollo de la Yuca
CONCADE	Consolicadion de los Esfuerzos de Desarrollo Alernativo
Ha	hectare
MT	Metric ton
M3	Cubic meter
PPM	parts per million
TM	Tonelada metrica
USD	U.S. dollar

Executive Summary

Cassava is a major staple in the tropical areas of the world, and processing its roots for starch and other products has been the basis of substantial industries in various countries. It is a prominent crop in the Chapare region of eastern Bolivia. It requires few inputs and is robust. In Latin America, there are examples of successful projects and private sector developments that involve cassava produced or processed by many small-scale producers. These factors make cassava-based development of interest in the Chapare.

Part I of this report comprises 1) case histories of medium-scale development initiatives based on processing cassava in Latin America, with possible application in eastern Bolivia, 2) notes on prior efforts to develop cassava in Eastern Bolivia, 3) presentation of a basic bibliography regarding such projects and general issues of cassava-based development, and 4) discussion of alternatives for cassava-based development, with potential application in the Chapare.

Several case histories concern starch extraction factories: a medium-sized producer in Bolivia, a large-scale producer in Brazil, a medium-sized producer in Colombia, a fairly large one in Argentina, a producer of modified starch in Venezuela, and a small plant in Colombia. The next cases are farmer-owned plants for animal feed in Colombia and Brazil. Finally, there is the program to produce flour for human consumption in Venezuela and that to produce alcohol in Brazil.

Conclusions based on the case histories are,

> C1. Raw material supplies are critical and complicated. Some projects have failed because farmers did not produce or sold to alternative markets. Relations between processor and producer are very important. The processor can and should plant some of the cassava he needs, but not all. There is enough variation in demand so that the farmers absorb fluctuations, while the processor's production provides raw material when producers are unwilling or unable. On the other hand, producers can associate to form successful enterprises with fairly simple processing technology. In that case, the non-member suppliers absorb demand fluctuations. Finally, in temperate areas, some of the raw material variation is due to seasonality.
>
> C2. Large processing plants do not use 100% of installed capacity, and even small ones rarely do. To be viable, large plants with high investment costs require using more than half of installed capacity. However, low cost, simple plants associated with producers (who cab sell to alternative markets) can survive with less use of capacity, at the cost of less dynamism.
>
> C3. Competition takes varied forms. There is competition for raw material, particularly with the fresh market. Other products compete with cassava. There is international competition.

C4. Agricultural production factors are relevant in several cases. Larger, commercial producers need high yields to prosper. But other projects survive with low-technology and low-cost processing, coupled with limited agricultural yields on small-farmer fields.

C5. Although cassava is an attractive crop because it is rustic, high-yielding and very adaptable, and although the Brazilian or Thai starch industries are wonderful cases of industries based on intermediate and state-of-the art technology, programs to replicate those successes are not guaranteed success, and there are too many cases of dramatic failure.

C6. Success can take several forms. In some cases, factories are dynamic and expanding (e.g. Yamakawa). In others (Atlantic Coast, Ceara), the processing component is stable, but static. The economic benefit of some plants is that they put a floor under root prices, while farmers seek higher prices in the preferred fresh market. Farmer organization and training is a collateral, but important, benefit in some cases.

C7. Models for cassava-based development are illustrated in these cases: factory investments with small-scale producers, organized farmers processing for market, assistance to small- scale, and medium-technology factories.

C8. In general, cassava starch will continue to be an important commodity. In some situations, it cannot compete with low-cost, subsidized agricultural inputs, and feasibility studies must include realistic market assessment.

Elements from the history of cassava in the Chapare are presented next. The conclusions are,

C9. The high humidity, precipitation and clouds of the Chapare affect processing feasibility for dry chips for animal feed, and possibly for other products.

C10. Bolivia has been interested in processing technology and CIAT has provided and is providing technical assistance, but the path forward is not clear.

C11. The Bolivian market has been somewhat insulated from the world market, with higher raw materials and finished starch prices.

C12. The review team did not find a serious market study for cassava and cassava products in Bolivia or for export.

The bibliography and review of literature follow. Conclusions include,

C13. As with exported Brazilian machinery and large factories for cassava flour for human consumption, these articles provide information on cases of attractive initiatives that did not lead to substantial results, as well as successes. The projects to support small-scale factories for flour for human consumption, for example, have been a disappointment, principally because of the competition with low-cost wheat (subsidized by producing countries) and wheat flour imports.

C14. Some of the issues illustrated are producer-processor relations (focusing on raw material supply, prices and trust/hazard); farmer participation in projects; markets (prices, competing commodities, and verification of markets before investment); the relationship between socio-economic and geographic factors and technology acceptance; effluent management (impact, cost); processing efficiency (plants operating well below 100% of capacity and root:starch conversion ratios well above 4:1) .

We discuss alternative technology and scale options for the Chapare, and alternative products, and then present the following alternatives for casssava-based development for consideration:

1. A large central factory producing starch using flash dry technology.
2. A smaller scale plant using artificial drying to produce animal feed.
3. A medium scale plant for animal feed.
4. A marketing group to sell fresh roots for human consumption.
5. A farmer-owned factory, of medium scale, for starch.
6. A single-owner, medium scale factory for starch.
7. A mixed plant for starch, animal feed, and fresh roots.
8. Wholesale production of roots for starch.
9. No processing technology, agronomy focus to produce roots.

Part II comprises a review of the proposal for a starch factory in the Chapare, based on the document "Proyecto de Factibilidad: Produccion de Almidon de Yuca dentro del Marco del Desarrollo Alternativo," presented by the Empresa Almidonera Botega Ltda. and the Productores de Yuca del Tropico de Cochabamba.

The proposal for the large starch factory has some strengths: known technology, known and saleable product, raw material appropriate to the region, prices for roots projected at current levels, price for starch at Brazil levels, and an offer for private sector financing of a substantial proportion of the investment cost.

There are some unknowns: farmer acceptance, measures to handle effluents, measures to deal with high ambient humidity, modest adjustments to the equipment budget.

There are several factors in which the proposal uses the most optimistic possibilities as givens: 100% utilization of capacity by Year 3, farmers providing raw material for that level of utilization by Year 3, root:starch conversion ratio of 4.0:1, starch price to root price ratio of 7.8; farmers supposed switch to monocrop production and to get experimental station yields immediately; factory risk limited to plus or minus 5% of costs and income; and agricultural risk limited to plus or minus 10% of costs and income.

Some of the assumptions are very unlikely: ability to compete with Brazil and Thailand on the world market, ‘guaranteed’ sales, and a jump in farmer yields from 6 MT to 22.5 MT on the fields of 1,136 farmers.

A moderately more rigorous and realistic sensitivity analysis shows plausible scenarios in which the project does not reach minimal returns, even without running worst-case scenarios.

One way to restore the project to minimal feasibility, would be to reduce fixed costs by 30% with no loss in capacity. Alternatively, with what we consider to be modest risks, the cost of roots has to be reduced from $45/ MT to $35 or perhaps $24 per ton (the latter corresponding to current Brazilian prices in Parana State). We suggest several ways that the proposal might be modified to reduce costs. Even with these changes, the likelihood of competing on the world market is slim.

The proposal does not have enough information on social and environmental factors. There are significant issues in these areas. Even if the technical and economic aspects of the proposal are fixed, it is not sure that it would pass analysis from the social and ecological side.

As it stands, we recommend against funding implementation of the proposed starch factory.

We recommend further development of alternative proposals for lower-cost investments in cassava-based development aimed at the Bolivian domestic market.

The following steps are low-cost, preliminary steps towards a decision about cassava-based development in the Chapare.

1. Find out if Botega is still interested in the project, and if Botega could respond to the issues raised in this report.

2. Find out if Botega would be interested in participating in a smaller factory for Bolivian market.

3. CIAT visits Chapare in January and February, 2000. Get more information on alternative developments.

4. Find out if feed manufactures and animal producers are interested in cassava flour for animal feed.

5. Do cost estimates and analysis for alternative cassava-based development. Include options for the shift to monocrop and for cassava remains supplementary, low-cost

crop. Include technology and market options identified in this report, and include single-owner and farmer-owners options.

6. Obtain preliminary field data using rapid rural appraisal techniques: farmer opinions, current prices, environmental issues, etc. Re-analyze existing survey data.

7. Prepare policy responses to issues raised in this report regarding environmental and social issues.

Introduction

Cassava (yuca in Spanish, mandioca in Portuguese, Manihot esculenta) is a major staple in the tropical areas of the world, and processing its roots for starch and other products has been the basis of substantial industries in various countries. It is a prominent crop in the Chapare region of eastern Bolivia. It requires few inputs and is robust. In Latin America, there are examples of successful projects and private sector developments that involve cassava produced or processed by many small-scale producers. These factors make cassava-based development of interest in the Chapare.

Part I of this report comprises 1) case histories of medium-scale development initiatives based on processing cassava in Latin America, with possible application in eastern Bolivia, 2) notes on prior efforts to develop cassava in Eastern Bolivia, 3) presentation of a basic bibliography regarding such projects and general issues of cassava-based development, and 4) discussion of alternatives for cassava-based development, with potential application in the Chapare.

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The team that developed this document consisted of:

Dr. Rupert Best	Manager Rural Agroenterprise Project and Former Head, Cassava Program, CIAT	Cassava expert
Ing. Bernardo Ospina	Director, CLAYUCA	Cassava expert
Dr. Steven Romanoff	DAI	Team leader

Each of the team members has worked in cassava-based development projects. As the former head of CIAT's Cassava Program, Dr. Best has general expertise with cassava, and his specialty is processing technology. Ing. Ospina has nearly 20 years experience implementing cassava projects in Colombia and Brazil, where he worked with EMBRAPA. Dr. Romanoff led a cassava-based project in Ecuador, has been a team-leader for DAI, and has substantial experience with development projects in Latin America. Ing. Ospina and Dr. Romanoff have done short-term work in the Chapare and Bolivian lowlands.

CONCADE began this review by providing a copy of the starch factory proposal. As preparation for this report, CIAT developed a file of case histories of cassava-based projects that were meant to affect 500 or more ha. and that involved processing roots. CIAT also conducted a literature search on such projects. The points that the team found most relevant from these cases and literature are displayed and numbered in the text using the format C1, C2, C3, etc.

The review team met in Cali, Colombia to discuss the project proposal. Dr. Romanoff prepared a draft of this report for review. Then the review team and Dr. James Wolf (DAI) made suggestions for the final draft, also prepared by Dr. Romanoff.

Part I. Cassava-based Development in Latin America

In Part I of this report, we will present information on cassava-based development in Latin America and define several alternatives that may be applicable in the Chapare.

Case Histories of Cassava-based Development

Apart from the major cassava-based industries in Brazil and traditional production in most of South and Central America, there have been a substantial number of successful cassava-based development projects in Latin America, some assisted by government projects and some purely private sector. Products include starch (private sector in Brazil, Argentina, Colombia, etc.), animal feed (development projects on the north coast of Colombia, Ceara State in Brazil), fresh roots (Colombia coffee areas for diversification, Cuba), waxed and frozen roots (Costa Rica for export) and others. However, there have also been a number of unsuccessful projects, some based on imported Brazilian machinery.

As part of this review, we have gathered basic information on 10 cases of cassava-based development in Latin America, all using processing technology and all involving 500 or more ha. of production. Some are successful, others failures. From these cases, including the opinions of participants, we draw insights for judging feasibility of future projects.

Table 1. Cases of Cassava-based Development

Company or Project	**Country**	**Product**	**Capacity (roots used)**	**Use of capacity**	**Degree of Success and Lesson learned**	**Problems or negative factor**	**Strength or positive factor**
INALCRUZ	Bolivia	Starch	3 MT/ hour	< 18% 10 % in 1999	Surviving Better several small plants than 1 large Involve farmers	Lack raw material, working capital Effluent problem	No lack of demand Low cost plant: $200,000
Amidos Yamakawa	Parana, Brazil	Starch	300 MT/ day	55%	Success. Must use > 50% capacity	Raw material, competition, plant cost 1.4M	Sufficient demand
Almidones Nacionales de Colombia	Colombia	Starch	108,000 MT/ year	10 – 25%	Moderate success. Must produce > 20% of raw material	Lack working capital, competition, cost: 8M	Good yields and agronomy
Cooperativa Agrícola Industrial San Alberto	Argentina	Starch	250 MT/ day	4 months/ yr. 100% 5 months closed	Moderate success. Company buys 50% raw material Leave yuca 2 years/ cycles	Seasonality of production, Other crops attractive, International competition BR,Para. Cost: 1.5M	High efficiency for a few months season
Agro-Pecuaria Mandioca	Venezuela	Starch, modified starch	200 MT/ day	60%	Moderate success. Sell modified starch	Lack raw material, cost of labor	Good agronomy, is expanding

					Reduce area planted, increase yield		
COOPALTOL	Colombia	Starch	1 MT/day	100%	Moderate success. Maintain good relation with producers	Plant too small, too many buyers, lack of norms, low starch varieties	Good agronomy; low investment $120,000
Costa Atlantica Program of small plants	Colombia	Chips, animal feed	15 – 20 MT/ year per plant 138 plants, total 2-3,000 MT/ year	50 – 60%	Success and stable, but not expanding Associated with producers, and integrated prod/ process/ market Social benefits important	Lack of land and credit Low agric. Productivity	Low investment: $15 – 20,000 Producer/ private sector integration
Ceara program of small plants	Brazil	Animal feed	15 – 20 MT/ year per plant 157 plants, total 2-3,000 MT/ year	15 - 20%	Moderate success, but low use of capacity. Associated with producers, and integrated prod/ process/ market Social benefits important	Lack of coordination among dispersed plants Lack of land, working capital Low agric. Productivity	Low investment: $9000/ plant, total $1,400,000 Producer/ private sector integration
Ministery of Agriculture	Venezuela	Pellets for animal feed	65,000 MT 6 cassava drying plants	0 –5%	Failed for lack of production, lower-cost competing products	Farmers ignored Market badly unanalyzed	Well funded 20 million US$
PRO-ALCOOL	Brazil	Alcohol	297 million liters alcohol año 180 liter/ton of cassava roots (1.5 million new hectares of cassava)	0-5%	Failed. Product not price competitive Lack of production	Cassava yields lower than expected Areas dedicated to project badly chosen	Know how of alcohol production from cassava developed

Among the unsuccessful experiences, we note several that involved importing Brazilian processing equipment, especially in the 1970's.

Table 2. Cases of Unsuccessful Introduction of Processing Machinery

Period	**Country**	**Use of Machinery**
1970's	Colombia, coffee area	Processing machinery never put to use; but roots sold successfully for fresh market
mid-1970's	Panama	For flour substitution; not working
mid-1970's	Jamaica	For flour substitution; over-dimensioned; no supply at

		reasonable price
1980's	Peru, Ucuyali River	Small area processed; not working
mid-1970's	Venezuela, military	Not put to use or not working

The cases presented in the preceding tables suggest several factors that have influenced the progress of cassava-based projects that are relevant to the proposed project. The cases are presented as Annex I of this report. Conclusions from the case histories include:

C1. Raw material supplies are critical and complicated. Some projects have failed because farmers did not produce or sold to alternative markets. Relations between processor and producer are very important. The processor can and should plant some of the cassava he needs, but not all. There is enough variation in demand so that the farmers absorb fluctuations, while the processor's production provides raw material when producers are unwilling or unable. On the other hand, producers can associate to form successful enterprises with fairly simple processing technology. In that case, the non-member suppliers absorb demand fluctuations. Finally, in temperate areas, some of the raw material variation is due to seasonality.

C2. Large processing plants do not use 100% of installed capacity, and even small ones rarely do. To be viable, large plants with high investment costs require using more than half of installed capacity. Low cost, simple plants associated with producers (who sell to alternative markets) can survive with less use of capacity at the cost of less dynamism.

C3. Competition takes varied forms. There is competition for raw material, particularly with the fresh market. Other products compete with cassava. There is international competition with processed products. For example, within the Southern Cone region, Argentina, Brazil, Paraguay and Bolivia all produce cassava starch.

C4. Agricultural production factors are relevant in several cases. Larger, commercial producers need high yields to prosper. But other projects survive with low-technology and low-cost processing, with limited agricultural yields on small-farmer fields.

C5. Although cassava is an attractive crop because it is rustic, high-yielding and very adaptable, and although the Brazilian or Thai starch industries are wonderful cases of industries based on intermediate and state-of-the art technology, programs to replicate those successes are not guaranteed success, and there are too many cases of dramatic failure.

C6. Success can take several forms. In some cases, factories are dynamic and expanding (e.g. Yamakawa). In others (Atlantic Coast, Ceara), the processing component is stable, but static. The economic benefit of some plants is that they put a floor under root prices, while farmers seek higher prices in the preferred fresh market. Farmer organization and training is a collateral, but important, benefit in some cases.

C7. Models for cassava-based development are illustrated in these cases: factory investments with small-scale producers, organized farmers processing for market, assistance to small- scale, and medium-technology factories.

C8. In general, cassava starch will continue to be an important commodity. In some situations, it cannot compete with low-cost, subsidized agricultural inputs, and feasibility studies must include realistic market assessment.

Experience in the Chapare and Eastern Bolivia

Another source of information relevant to development in the Chapare is the effort of IBTA to introduce cassava-processing technology in that region.

Between 1990 and 1992, IBTA conducted cassava drying trials in the Chapare using sun-drying, a technique that is used in Colombia, Ecuador, Brazil, Thailand, etc. Drying time for chips was 4 to 5 days. Since chip quality suffers after 3 days, the trial was not a success. Covering the drying floor with plastic did not help. The humid conditions in the Chapare made natural drying impractical.

In 1995 and 1996, IBTA implemented a mixed system, combining an artificial drier with solar drying, for chips to sell in Sta. Cruz. High labor and transportation costs result in costs higher than returns, and IBTA has requested assistance from CIAT.

IBTA has a collection of local varieties and varieties from CIAT and (since last year) Parana. No varieties have been released, and characterization work remains to be done.

One of the case histories for this report is the INALCRUZ private plant in Sta. Cruz. From this case we find that starch processing can work in eastern Bolivia, but the prices of both raw materials and starch are higher than on the world market. Raw material has been a problem. The owner suggests more, smaller processing plants.

A positive factor for cassava-based development is that local expertise and international cooperation exist. For example, the Instituto de Investicacion Agricola “El Vallecito” of the Universidad “Gabriel Rene Moreno” has personnel experienced in germplasm and integrated pest management (Ing. Mateo Rojas) and plant breeding (Ing. Juan Lenis and Ing. Maria Lisi). The Instituto recently hosted an international meeting on “Investigacion Tecnologica de Mandioca (Yuca) en el Cono Sur” sponsored by IICA under its PROCISUR program (6-7 December, 1999).Additionally, the IBTA (Instituto Boliviano de Tecnologia Agrícola)-Chapare, has had involvement with cassava and some of its staff have been trained at CIAT.

CIAT has done two cassava courses in eastern Bolivia (1990). Recently, Bolivia joined the international network coordinated by CIAT known as CLAYUCA. CIAT is sending an expert in cassava processing to the Chapare in January/February, 2000 to look at prospects for artificial drying of cassava chips for animal feed.

From this experience, we can learn:

C9. The high humidity, precipitation and clouds of the Chapare affect processing feasibility for dry chips for animal feed, and possibly for other products.

C10. Bolivia has been interested in processing technology and CIAT has provided and is providing technical assistance, but the path forward is not clear.

C11. The Bolivian market has been somewhat insulated from the world market, with higher raw materials and finished starch prices.

C12. The review team did not find a serious market study for cassava and cassava products in Bolivia or for export.

Relevant Literature

CIAT compiled a basic bibliography on cassava projects, and some general information on cassava, for this review. The bibliography and copies of references include both published and manuscript sources. It is provided as Annex II of this report.

Sources are provided on cassava factories and factory-based processing projects. The Brazilian starch and Thai animal feed pellets industries are similar to the Botega proposal (Part II of this report) in that they involve factory processing with large numbers of small-scale producers, though in the Brazilian case, larger and more technical farmers are becoming prominent.

An alternative model shifts more of the processing tasks to farmer organizations using low or medium technology. Several articles are presented on the projects in Colombia and Brazil, which involve capacity to process 500+ ha. These projects have gained good will and collaboration by small-scale farmers. They are stable but have not been expanding after initial impetus and removal of incentives, their profitability having been limited by the opening of the respective country's economies. Recently, manufacturers and consumers of animal feed have shown interest in initiating such projects on a large-scale.

Still another project model is taken from Cauca, Colombia, where the goal was to improve existing small- and medium-scale processing of cassava into starch. Several articles are provided.

Finally, the bibliography includes general sources on cassava processing, cassava, and cassava-based projects.

Some of the lessons from this literature are as follows:

C13. As with exported Brazilian machinery and large factories for cassava flour for human consumption, these articles provide information on cases of attractive initiatives that did not lead to substantial results, as well as successes. The projects to support small-scale factories for flour for human consumption, for example, have been a disappointment, principally because of the competition with low-cost wheat (subsidized by producing countries) and wheat flour imports.

C14. Some of the issues illustrated are producer-processor relations (focusing on raw material supply, prices, and trust/hazard); farmer participation in projects; markets (prices, competing commodities, and verification of markets before investment); the relationship between socio-economic and geographic factors and technology acceptance; effluent management (impact, cost); processing efficiency (plants operating well below 100% of capacity and root:starch conversion ratios well above 4:1) .

Bibliographic Annotations

This section indicates themes from some of the sources being supplied to the project.

Cassava-based projects with small scale farmers and small-scale industries

Brazil	Animal feed	Ospina et al. 1999 Henry et al. 1999 Ospina and Wheatley 1991 Vilela 1987	Analysis of factors that led communities to produce dried cassava in the Ceara project Summary of projects in Ceara, Sao Paulo, with notes on sustainability An early report on the Ceara project. Chips for animal feed.
Colombia, Ecuador. Brazil, India, Peru, Philippines	Various	Wheatley et al. 1995	Part II comprises product development case studies from indicated countries.
Peru, Colombia, Thailand	Flour, starch, Sour starch, Modified starch	Dufour, O'Brien and Best (eds.) 1996	Some projects described, including research and some industries described Ch. 5. Hopeful description of a Peruvian project to produce flour in a humid forest area that has not

			succeeded (Dominguez, Guzman, Aquino). Ch. 6. Description of the ongoing sour starch industry in Colombia, based on small-scale processing; 99 factories surveyed; problems identified: cassava supply, working capital, plant capacity, spare parts, transport, plant site, starch quality, water supply, knowledge (Mosquera et al.). Ch. 28. Description of processing technology in small-scale starch processors in Brazil based on 2 plants (Marder et al.). Notes water consumption and 'highly polluting nature of waste waters', effluent discharge and damage to fish and animals. Issues include root supply, financing, labor cost, packaging costs, marketing, quality and cost effective effluent treatment. Ch. 31. Trial of a flour processing plant in Colombia. While the animal feed industry has been stable, this initiative did not grow (Figueroa) Ch. 39. More on this project. Ch. 41. Trial of flour processing in Indonesia. The trial did not create an industry (Setyono, et al.)
Colombia	Animal feed	Perez-Crespo 1991 Gottret and Henry Gottret and	General analysis of the project to promote animal feed processing plants, with discussion of the project, integration with agronomy, farmer organization, impact assessment, etc. Discussion of impact of the Colombian animal feed processing plants

		Raymond	Impact analysis
Colombia	Sour starch	Gottret et al. 1999 Gottret and Henry 1997 Alarcon and Dufour 1998 Henry and Gottret 1998	Characterization of the sour starch industry in Colombia, with information on technology, based on a survey of 47 plants. They use 82% of installed capacity. Processors produce 8% of raw material. 3% treat waste waters. Conversion ratio is 4.9. Study of technology adoption by small scale processing plants. Description and recommendations for the sour starch factories. Discussion of technology adoption.
Ecuador	Animal feed and starch	Romanoff and Rodriguez 1989	Project document illustrating local team building.
		Romanoff 1986	Project document at start-up.
		Ruiz 1996	A participant point of view.
		Romanoff 1989	Practical guide for organizing farmers in processing companies.
General	Animal feed	Henry and Correa 1991	CIAT produced many documents on the economics of animal feed uses of cassava, of which this is an example. Animal feed use in Latin America is expanding rapidly and cassava can substitute for part of the imports. But the world price of maize and sorghum sets the price of dried cassava at modest or low levels.

Cassava factories and factory processing projects

Colombia	Flour	Proton Ltda 1999	A project for a factory to produce 25,000 MT of flour per year. Includes waste treatment.
Colombia	Starch	Jaramillo 1998	Basic description of starch processing, in Spanish
Zambia	Flour and modified starch	United Nations 1983	A project for a factory to produce flour and starch from sun-dried chips, with more general discussions of cassava use. Effluents mentioned.

Zambia	Sun dried chips	United Nations 1984	The factory described in UN 1983 was to be fed with dried chips, not fresh roots.
Indonesia	Flour	Domardjati, et al. 1996	Pilot and research focus, with background on Indonesia's use of cassava
Thailand	Starch and other products Pellets and starch	Maneepun 1996 Ch. 36 of Dufour, O'Brien and Best (eds.) 1996 Atthasampunna 1990 Henry and Gottret 1991	Some information on Thailand's cassava industry and where it is going. Modern factories work on a 5:1 conversion of roots to starch Overview of the Thai industry, which shows factories and small-scale producers Discussion of adoption of a variety in Thailand
India	Starch	Spac Tapioca products	An internet site on a processing factory in India. Note use of hydrocyclones. Note that Brazilian ABAM is also on the internet.
Brazil	Farinha etc.	Scholz 1971	Description of farinha technology in NE Brazil
Argentina	Starch	Walter et al. 1991	An intermediate technology factory proposal.

Chapare documents

	Cassava agronomy	Chumacero 1993	Preliminary characterization of local and imported cassava varieties
	Cassava characterization	Vargas 1997	Example of basic technical work on cassava agronomy.
	Cassava general	Vargas 1998	An extension folder.

General introductions to cassava and cassava processing

	Cassava, especially processing	Balagopalan et al.1988	Comprehensive, basic introduction to cassava, with emphasis on processing.

	Root and tuber products	Wheatley, et al. 1995	Describes an 'integrated approach to product development' and stages for a root/tuber processing project.
	Integrated projects	Ospina, et al. 1996 Ch. 36 of Dufour, O'Brien and Best (eds.) 1996 See also Henry and Best 1991	CIAT's approach to integrated cassava research and development projects
	Demand	DTp Studies Inc. Ostertag 1993 Henry and Gottret 1996 Gottret et al. 1997	Draft of a discussion of demand for cassava in national markets around the world, with observations on starch markets. Starch demand, not limited to cassava starch Assessment of demand for cassava, an example of several publications on demand from CIAT. Example of a discussion of demand at the national level, with a section on cassava starch. Notes prices of cassava starch in various countries: Colombia: $525, Venezuela: $300; Brazil: $357; Thailand: $233.

Alternative Investments in Cassava-based Development

The options for Chapare development are a mix of technical options, products and social alternatives.

Some of the options for technology and scale of operations for cassava-based development in the Chapare include the following:

1) a large-scale factory processing for export, with small-scale producers, as presented in the Botega proposal reviewed in Part II;

2) a factory, but with modifications such as have been suggested in this report;

3) a medium-scale factory for the domestic market, possibly like the Cauca model or a smaller version of the INALCRUZ model;

4) no factory in the Chapare; rather, broker wholesale production for INALCRUZ, other industry in Sta. Cruz, or a drier area near the Chapare;

5) small to medium-scale processing with organized producers, following the models of the Atlantic Coast in Colombia or Ceara, Brazil;

6) agronomy, with no processing component;

7) nothing with cassava.

The different models may produce one or a mix of several products: starch for industry and human consumption; flour for animal feed plants; and fresh roots for human consumption.

1) The animal feed alternative is based in strong and growing demand for substitutes for maize in animal feed rations. It is not a high-profit option, and a plant would face problems with humidity and supplies.

2) A small or medium-scale starch factory is based on domestic demand for starch and the experience of a medium-scale producer in Sta. Cruz. Again, it faces the problems of humidity and supply.

3) The fresh root for human consumption option is attractive for the market of Sta. Cruz, but it would face an often erratic and limited market.

4) A processing plant could combine several of the small-scale alternatives. A factory could sell the best roots on the fresh market, process what it could for starch, and provide the remainder for animal feed. Some of the equipment can be used for any of the products, so there are modest economies of scale.

We do not suggest flour for human consumption in a situation that requires rapid results, because projects to produce flour for human consumption have not been very successful.

Combining the factors of technology, scale of operation, ownership and market, we suggest the following as examples of alternatives to be evaluated for cassava-based development in the Chapare.

Table 3. Alternatives for Cassava-based Development

Technology	Product	Market	Scale/ Investment * (USD)	Area planted (ha)	Investment $/ ha planted	Notes
1. Flash dry/ central plant	Starch	10% Bolivia 90% export	Large ($2,700,000)	2500	1080	Effluent problem
2. Small scale, artificial dry	Animal feed	Bolivia	Mid ($70,000)	60	1167	No effluent problem, market and price

						issues
3. Medium scale, artificial dry	“	“	Mid ($105,000)	120	875	“
4. Marketing group	Fresh Roots	Sta. Cruz	Mid-Small ($50,000)	80	625	
5. Farmer-owned factory, Medium scale	Starch	Bolivia, Chile	Mid ($200,000)	175	1142	Medium effluent
6. Private, Medium scale	Starch	Bolivia, Chile	Mid ($200,000)	175	1142	Medium effluent
7. Mixed	Starch, animal feed, fresh roots	Bolivia, Chile	According to options			
8. Wholesale production	Starch	INALCRUZ	Mid-Small ($50,000)	To be determined	low	Use existing factory in Sta. Cruz
9. Agronomy	Roots	Sta. Cruz, local	Nothing in processing			

Notes: * without working capital

It is notable that the investment cost per hectare of production is relatively constant in the alternatives listed, with the exception of a cooperative marketing venture for fresh roots, which involves less investment.

The Latin American experience provide examples of cassava processing that might work in the Chapare, as well as unsuccessful cases that indicate care in proceeding. Part II of this review concerns a proposal for a large, export-oriented factory.

Part II. Review of a Proposed Starch Factory in the Chapare

Part I has provided alternatives for cassava-based development in the Chapare. Part II is a review of the first option for cassava development in the Chapare: a large, central, modern processing plant supplied by a large number of small-scale producers to extract and market starch on the international market (see Basic Elements of the Proposed Project, below).

There are several audiences for this review. All are concerned with economic, social and environmental aspects of the project, but the emphases may be different. 1) According to the proposal, the Empresa Almidonera Botega Ltda. offers to finance a substantial portion of the project costs. We raise questions of economic and technical soundness and the social issue of relations between producers and processor that will be of interest to a private-sector investor. 2) From the point of view of the CONCADE project, we look at the project in terms of long-term feasibility, crop substitution and general environmental soundness. 3) From the point of view of the farmers of the Chapare, we are concerned principally with the economic interests of raw material producers and their participation in the processing plant.

Prior experience with cassava-based development (Part I of this report) suggests that this review should be rigorous. In the 1970's and 1980's there were projects for cassava-based development based on government action to substitute cassava flour for imported wheat flour, develop licit alternatives for illicit activities and use imported Brazilian machinery. Although some of those projects were of substantial size and cost, in several cases feasibility and markets were not examined vigorously, sometimes results were poor.

Criteria for project selection and evaluation have changed since the 1980's, and now projects must stand up to more rigorous examination from both economic and environmental perspectives. Therefore, this aims to be a straightforward review of the proposed starch plant, with recommendations of how to proceed.

Basic Elements of the Proposed Project

The Empresa Almidonera Botega Ltda proposes to implement a factory to extract starch from cassava roots. By its third year of operation, the plant would process 50,000 MT of roots to produce 12,500 MT of starch.

The cost of the plant would be proposal is $3.3 million, broken down as $1,824,000 equipment and installations, $377,000 civil works, $50,000 various, $5,200 land, $210,000 vehicles, $11,000 furniture, and $782,000 working capital (mostly raw materials).

The financing proposal is $1,000,000 credit (29%), $1,700,000 cash from Botega (50%), and $675,000 in raw material advanced by farmers (20%).

Raw materials would be supplied by 1,136 families, each producing on 2 ha. of land. Cassava is currently grown for subsistence and marketing as fresh roots.

Technical Aspects of the Factory Proposal

The proposal presents agricultural production technology and factory processing technology. The agricultural technology proposes to apply improved varieties and agronomic practices to increase yields and assure a constant supply of raw material. The processing technology proposed involves fragmenting the roots at the factory, milling them, extracting starch and water in centrifuges, and then drying the starch with hot air using a flash drier. The proposal is not unusual for processing cassava roots into starch in Brazil, with the exception of lack of information about effluent management and taking into account several observations made below. We begin the review with the agricultural technology.

Agricultural Technology

Projected yields (Table 8.2) of 23 MT/ ha are not unusual for commercial producers and are within the potential of the crop, but they are higher than current yields in the Chapare. The (unstated) source of the yield data presented is characterization plots on an experimental station. Small farmers do not get the same yields as larger, commercial farmers or experimental farms, so on-farm yields should be projected at lower figures (perhaps 1/3 less, pending better data). Moreover, characterization plots are small and subject to statistical variation. It appears that the author of the project selected the high yielding varieties from a longer list of very preliminary characterization results; we do not know if the selected varieties would perform consistently. The projections are for fields of only cassava, though intercropping is common among Chapare farmers.

The author of the project apparently selected the best varieties from the following report (Chumeacero 1993):

Table 4. Experimental Station Yields in the Chapare, 1992

VARIETY	YIELD MT/HA	VARIETY	YIELD MT/HA
CHBol-01	19	SCBol-15	19.5
CHBol-02	22	CR-16	16
CHBol-03	14.4	CR-17	15.8
CHBol-04	18.3	CHBol-18	11.3
CHBol-05	14.4	CHBol-19	10.4
CHBol-06	17.1	Col-20	32.5

CHBol-07	14.1	YBol-21	12.4
CHBol-08	15.2	YBol-22	15.1
CHBol-09	25.3	CHBol-23	13.5
CHBol-10	19.2	CM3306-4	21.9
CHBol-11	19.1	CM3291-4	13.2
CHBol-12	19.5	CM3372-4	8.1
CHBol-13	22	CM2766-5	18.2
CHBol-14	17.7	Mean	17.2

Schedules and techniques for producing planting material is not specified (section 8.3). Apparently, the project would plant in Year 0, while the equipment is manufactured and the plant constructed. Getting seed for 1136 ha of cassava in the first year is not a trivial task, even if local varieties are used. A good ratio for multiplying plants is 1:7, so the 1136 ha planted would require finding and harvesting 162 ha of planting material of the proposed varieties.

The agricultural cycle (Table 8.4), with bush fallow of 1 – 2 years in a 3 year cycle is interesting. Continuous production of annual crops in the humid Amazonian lowlands is technically possible, but farmers do typically keep fallow in the farming system. However, we cannot say if the fallow is long enough. The graphical agricultural calendar (Table 8.3) should be edited because the harvest is year-round.

The estimate of area cropped and harvested assumes that the processing plant is used at capacity in Year 3 and thereafter (Table 8.5). We provide a risk analysis later in this report.

Currently, cassava is a rustic, low-input cultivar in the Chapare. Sometimes it is intercropped with other, higher-value crops. It is also the succession to more demanding crops in a cycle that includes fallow. The proposal, while keeping a fallow, requires farmers to make cassava a monocrop and to grow it as a cash crop with more attention and inputs, a change that is supposed to happen very quickly, perhaps an unrealistic projection.

We will return to the issues of yield and farmers' practices later in this report.

Processing Technology

The factory technology proposed is not unusual in Brazil, but we have several observations and comments. Our copy of the proposal did not have the descriptions for equipment items 17 through 29; the technology is not exotic and the missing information is unlikely to modify general conclusions.

With regards to the general input/output ratio:

The proposed conversion ratio from roots to starch is 4.0. The normal range with roots having 35% dry matter would be between 4.0 and 5.0. In the Thai literature appended, for example, a 5.0:1 ratio is used. The value proposed for the Botega factory is possible, but it presumes very efficient operation of the plant. It would be prudent to raise it for projections.

Regarding Annex 24: After the batteries of cyclones, it may be worthwhile to put in filters to recoup about 3% of starch that would be lost.

With regards to environmental relative humidity:

Very high levels of rainfall occur in parts of the CONCADE project area. At the base of the Cordillera, over 7,000 mm per year have been recorded. In the western area, rainfall is commonly 5,000 mm per year with no dry season. There is a decline in rainfall as one proceeds east from Villa Tunari and north from the cordillera. In areas to the east of Rio Sajta, the annual totals may be 50% or less of that in the western part of the project area, with a relatively dry season. In general terms, we may divide the area into a very wet zone (3250 – 5500 mm) and a wet zone (2250 – 3250 mm). Both areas are humid.

Flash drying at 130 degrees C (p.34) is appropriate in an environment with moderate humidity. In high humidity, the flash drier may require 160-165 degrees C., which is the experience in Guayaquil or Coca, Ecuador. There are two ways to manage this situation. 1) The steam to generate this temperature in the drier may be at 185 degrees C, and the materials for construction are correspondingly more expensive. 2) The air can be dried before it goes into the flash drier, with the cost of drying (e.g. for making ice to cool the air before it goes into the flash drier) added to the budget and the energy requirements of the project.

The use of normal paper bags for the finished starch is not appropriate in the high humidity of the Chapare. Cassava starch at 13 % water content absorbs humidity from the air. The bags should at least be multi-layer, with a plastic moisture barrier because of the humidity of the Chapare.

Since there are differences with regard to the energy requirements for drying between the CIAT experts and the proposal, we would like backup of calculations and a technical discussion.

Environmental humidity contributes to the need for more stainless steel.

With regards to materials used to make equipment:

CIAT experts recommended that several pieces of equipment made from carbon steel in the list of equipment be made from stainless steel, in addition to those already listed as stainless steel. There are two reasons: to avoid deterioration of the equipment and to prevent contamination of the product. This will raise prices.

Items that probably have to be made of stainless steel:

9. triturador de raizes
11. alimentador dosador
12. desintegrador
14. peneiras rotativas extratores
15. moinho de massa
30 vacum filter
31 flash drier
32 silo for starch
probably others

With regards to the lack of explanation of plans to process subproducts (fiber, leaves, stalks):

Items 39, 40, 41, and 42 and Annex 32 are for processing fiber – they are not explained and the economics of producing the fiber is not explained.

Item 43 appears to be the drier for the aerial portion of the plant, a moderately costly investment – this is not explained and the economics of producing dried leaves and stems is not explained, nor is the market for the product identified.

Annex 34 We were not clear on the function of this item for processing subproducts.

With regards to effluent treatment:

The absence of a technical discussion of effluent treatment must be rectified before any decision on this proposal. Effluent treatment with this kind of technology and in this environment is a major issue. We return to this theme in the sections on economic and environmental aspects of the proposal.

With regards to the presentation of information and adequacy of the presentation:

The chart "Flujo de Proceso para la Obtencion de Almidon de Yuca" should be edited to show the correspondence between the steps in the process, the equipment budget items and the illustrations of machinery.

"Eliminacion del primer subproducto cascaras" probably goes before "Cinta transportadora para la inspeccion ocular"

Annex 35 appears to be a drawing of the kind of tank used to transport cows' milk by truck, and there is no suggestion that the starch plant would use such a tank.

Inclusion of this drawing indicates that the final version of the study was not edited with sufficient care.

The presentation of the proposal, while written in an attractive style, needs more technical details. An equipment bid and study suitable for a decision would provide technical drawings of equipment with dimensions (the study provides artistic sketches); a more complete flow chart that allows easy cross-reference among the relevant sections (flow chart, explanation of process steps, equipment bid, and drawings); more precise information on fuel use and labor; more complete information on equipment capacities, etc.

Miscellaneous questions

In Brazil, hydro-cyclones are not in general use; however, their use should be compared with the recommended centrifuges because they use less water and energy.

We were not clear on the function of Item 36 if you have Item 6 – do they perform the same function? We were not clear on the function of equipment in Annex 20, which may be to break up lumps before flash drying.

Function of Item 15 was not clear.

Annex 28 is not clear – it may be for flow from the silo, not to the silo.

No information was presented on technical aspects of civil works.

Economic Aspects of the Factory Proposal

The feasibility of the project depends in large part on its profitability, and in this section we analyze costs, prices, markets, and risks. While we could use more information on several aspects of the project, there is sufficient information to do a rough sensitivity analusis in the project document, supplemented by technical knowledge of the CIAT experts.

Cost Information

Some information for the proposal was prepared in 1997. Equipment prices date from March 1998, and the study is from 1998. Equipment cost estimates should be redone with current prices and taking into account decisions on processing sub-products, use of stainless steel, effluent treatment and other items discussed in this report.

We saw several items in the text or graphics that we did not see in the budget:

lab equipment
possibly 2 more centrifuges (see step 9.2.13)
effluent treatment
Annex 35, Water tank
Annex 33, a tank for transporting cows' milk

Some minor costs should be added to the costs of production of cassava (Table 11.1): hand tools, transportation of inputs to field and product to purchase center, cost of treating planting materials, harvest wastage, farmer management cost.

Energy costs are somewhat underestimated. The annex table on energy consumption posits that gas consumption for drying will be 246 cubic feet per ton of roots [the annex table actually says consumption per ton of 'starch', an apparent oversight.], equivalent to 5 or 6 liters of diesel per ton of roots processes or 20 to 24 liters of diesel per ton of starch produced (given the conversion ratio of 4.0). CIAT experts estimate that the fuel needed to go from 45% humidity (the mash that enters the flash drier) to 13% humidity (the starch that comes out) will require 13 gallons of diesel fuel per MT of starch produced.

We have not reviewed budgets for civil works.

We have insufficient knowledge of administrative and cost aspects of importing equipment or implementing the proposed technology. We presume that the contract for implementation would be put out to bid.

The cost of effluent treatment is not included in the budget. This may prove to be a substantial omission if additional equipment is required. Although Brazilian factories handle the effluent at relatively low cost, the special conditions of the Chapare and the likely standards for an international project make that doubtful.

Cassava Prices

The proposal uses a price of $45/MT for roots, which is close to the present price in the Chapare for the fresh market or in Sta. Cruz for processing.

For a large scale plant with hopes of exporting, this price is high compared to Brazil, Thailand or other exporters. According to the bulletin of the Brazilian Association for Cassava Producers, provided as an annex to the study, they wanted a support price of about $40 in 1997 (R$40, at a time when the currencies were close), but the reality is that prices in Brazil are lower (see following table).

It is difficult to see how Bolivian starch could compete with Brazilian starch in most markets if the raw material is more expensive, given the other advantages for Brazilian processors.

If the price were lowered, however, it would be more difficult for cassava to compete with other licit or illicit crops in the Chapare.

Table 5. Price of Cassava (Root Prices, USD per Metric Ton)

Country, Region	Use	Price (USD/MT)
Bolivia, Proposal	starch	$45
Bolivia, Santa Cruz	starch	$40 - $50
Bolivia, Santa Cruz	fresh	$60 - $150
Brazil, Parana	starch	$20
Brazil, Northeast	farinha	$30
Argentina	general	$40 - $60

One advantage for a Chapare factory is the seasonality of cassava production that most affects Argentina, and also affects Parana. The ABAM bulletin provided notes the importance of continuous production through the year. Also, the Chapare may be able to compete with Brazil in Chile or southern Peru.

The economic relations with raw materials suppliers (farmers) are not adequately described. Farmers are to provide roots as their contribution to working capital, but how and when will they be paid for roots? Can they sell their stake in the business? After the initial period, will new farmers become stake-holders? How would eventual profits be distributed? Will benefits be divided according to the quantity of roots supplied (cooperative principal) or according to shares?

Finally, we note that in major producer/processor countries, such as Brazil and Thailand, the price of cassava roots is adjusted according to the starch content of the roots. We suggest that this option be considered for the present project.

Starch Price

Starch produced in Sta. Cruz, Bolivia, is selling at $540 / MT, according to a small-scale industry in that city (see case studies, Part I).

The ABAM bulletin attached to the proposal suggests a price of R$340/ MT (roughly equivalent to USD at that time). Starch from Thailand placed in U.S. ports varied between $357/ MT and $290 / MT between third quarter of 1996 and first quarter of 1998. Despite a reported price in Japan of $300 - $400/ MT (per ABAM bulletin), in fact Japan is importing at considerably lower prices.

The Botega proposal uses a projection of $355 / MT. This is appropriate because the price of starch for a large-scale industry hoping to export would surely be lower than the current Sta. Cruz price.

It is likely that the factory would be able to sell starch as proposed ($355/ MT in plant) to consumers in Bolivia or perhaps Chile – but we do not see how the factory could export to Brazil, the U.S. or Japan at that price. Perhaps there is some seasonal variation in Brazil or Argentina that might open a window.

If starch sells for $355 per MT and roots sell for $45 per MT, the ratio of starch to root prices is 7.8. This is a relatively low ratio: based on average prices 1990 –1995 reported by Henry and Gottret (1995), the ratio is 8.1 in Thailand, 11.3 in Brazil and 12.4 in Colombia. The 7.8 ratio of the proposal is just barely possible if the factory lives up to the proposal's very optimistic projections of root:starch conversion ratios, plant utilization, etc.

We return to the issues of optimistic projections and high root prices in the sensitivity analysis presented later in this report.

Summarily, it is likely that the starch will have to be sold for higher prices (limiting the markets where it can be sold) or the price of roots will have to drop (possible if farmers agree, but otherwise leading to supply problems).

Sub-products

Although apparently a drier for the aerial part is included in the budget at a cost of $210,000 (Item 43. Secador de Farelo), the costs and benefits of using the aerial part of the cassava plant are not estimated. Fiber is also produced as a sub-product. Since the benefits of selling subproducts is listed in the financial projection (Table 14.2), there should be a discussion of markets, demand, prices, etc.

Markets

Cassava starch is in competition with maize starch and other starches. It is an internationally traded commodity. The factors of competition are price, continuity of production and basic quality (impurities, acidity, color, biological content). There are no guaranteed markets.

The project states that "la venta del almidon de yuca se encuentra totalmente garantizada" (p.1). The market is said to be 90% export and 10% Bolivian domestic. Although some information on international trade is presented, it is of a general nature and not sufficient to constitute a market study. While it is possible that Botega has markets in mind, the project is not specific about markets and we would like information before expressing confidence that markets are guaranteed for starch at the prices projected.

We doubt the capacity of the project to export consistently at volume to the USA, the European community or Japan because of competition from Brazil and Thailand, for examples, and because some of the imports of these industrialized countries are modified starches, not the raw starch that would be produced in Bolivia.

Brazil is a large consumer of starch and hence a potential market, but it is also a producer and exporter with certain advantages. 1) Brazil currently exports, including to Bolivia. 2) Brazil has higher productivity and lower raw materials costs than Bolivia (compare roots purchased at $45/ MT in the current project, versus roots sold for $25/ MT in Parana; roots in Thailand, another exporting country, are also purchased for processing at $25 - $30/ MT). 3) Brazilian producers are already organized in the Asociaciao Brazilera de Almido de Mandioca (ABAM – see its web site). 4) Brazil can compete with Bolivia in Paraguay and Argentina, and both of those countries are producers.

Minimally, if the Bolivian product is to compete in Brazil, the producers will have to lower the price received to those of Parana State. But, as noted previously, if they lower the sale price of cassava, cassava may not be able to compete with coca or other, higher-value crops.

Still, there may be markets for Chapare cassava products. 1) The Bolivian domestic market should be characterized – it might be around 10,000 MT per year. The domestic demand for other cassava products (e.g. flour for animal feed) is growing and substantial, and feed plants are interested. 2) Chile is an interesting possibility for export because Bolivia is closer to Chile by land than is Brazil. The Chapare is also nearly as close to southern Peru as is the Peruvian Amazonian lowland, so that market might be possible. These options should be explored. 3) The seasonality of Brazilian Parana and Argentinean production may open a window for Bolivian starch in certain months. 4) Botega may have certain markets in mind and could be more specific about them.

Other Economic Issues

How will farmers finance expansion of their cassava holdings? Will there be a credit program? Are there sufficient credit-worthy farmers in the right areas? Will there be training in credit management, formation of solidary groups, etc.? The costs of a credit program have not been included in project costs.

Will CONCADE provide field staff for this project (see Social Aspects, below). If so, the cost should be provided and included in the IRR calculation from the project point of view.

Sensitivity and Risk Analysis

The proposal suggests a rate of return on the processing investment of 21%. As a rule of thumb, a project with social benefits should have an internal rate of return of 13%.

The sensitivity analysis is done by modeling 5% greater costs and 5% less income and does not change the decision to proceed.

We feel that there are factors that require a more realistic modeling of risk.

- Plant efficiency. The cases gathered by CIAT show that cassava-processing plants do not typically operate at 100% of capacity, even after being established for some time. Rather, plants operate at 50% to 65% of installed capacity. We will model 65% and 85% use.

- Delays. The cases also show that producer-processor relations are problematic. Producers sometimes do not plant as expected, or yields are less, or they sell to other people. These issues are especially problematic in the first years of a project, and they result in under-utilization of plant capacity. The region is subject to political turmoil, road blockage, strikes, etc. On the other hand, the all-year production in the Chapare is a positive factor. Still, we will model 0 use of the plant in the first year.

- Root to starch conversion ratio. The cassava conversion ratio of 4.0 is in the feasible range, but it presumes very efficient operations, and we need to verify starch content of roots on farmers' fields. We will model 4.5 and 5.0 ratios of cassava to starch.

- Cost overrun. Equipment costs may be higher than expected because of factors that we have noted in the technical review. The issue of effluent treatment is pending . When the issues of effluent treatment, cost updates, etc. are resolved, the cost of the plant may go up. We will model 10% and 30% increases in investment.

- Ordinary mix. We will model just one mix of the above factors.

After modeling these factors as risks, using values that are in no way extreme, we will attempt to rescue the project by showing the required economies in investment and raw materials costs that would restore a minimal rate of return for the project.

- Equipment savings. We reduce fixed costs and investment by 15% and 30%.

- Raw materials savings. First we cut root prices to $35, but with other variables still favorable. Then we cut root prices to $24 per MT with a mix of other factors that are somewhat realistic and not extreme.

The point of view of the IRR analysis is the processing plant. The project as a whole may wish to include some support costs in the calculations, such as extension costs. We have not modeled this.

The following table shows alternative scenarios and their effect on the internal rate of return of the project.

Table 6. Risk Analysis and Rescue Scenarios, Factory Component

% plant capacity used, year 1	% plant capacity used, year 2	% plant capacity used, year 3, 4+	Conversion ratio (roots: starch)	Investment cost (1.00 = as budgeted)	Internal Rate of Return	Scenario/ Comment	IRR Decision
6.a. Risk Analysis							
50	75	100	4.0:1.0	1.00	.21	Per project	Go
50	57.5	65	4.0:1.0	1.00	.08	Normal usage	Stop
50	67.5	85	4.0:1.0	1.00	.16	Good usage	Go
0	.5	100	4.0:1.0	1.00	.15	1 year delay	Go, marginal
50	75	100	4.5:1.0	1.00	.06	Normal ratio	Stop
50	75	100	5.0:1.0	1.00	-.13	Normal ratio	Stop
50	75	100	4.0:1.0	1.10	.17	Minor over cost	Go
50	75	100	4.0:1.0	1.30	.10	Over cost	Stop
25	55	85	4.5:1.0	1.00	0	Normal mix	Stop
6.b. Rescue Scenarios							
25	55	85	4.5:1.0	.85	.06	Fixed cost savings	Stop
25	55	85	4.5:1.0	.70	.14	Large savings	Go, marginal
25	55	85	4.5:1.0	1.0	.14	Roots @ $35/ MT	Go, marginal
0	32.5	65	4.5:1.0	1.0	.14	Roots @ $24/ MT	Go, marginal

Realistic projections of technical parameters thus put a strong downward pressure on what the factory can pay farmers for fresh roots. Those same parameters limit the profits that farmers could expect from their participation in the factory.

We now turn to the agricultural risk analysis. Again, the proposal's scenarios (costs increased by 10%, returns decreased by 10%) are not sufficiently rigorous. Here the criterion is simple: can cassava produce gross receipts at all comparable to competing crops? We calculate gross returns if

- Yields are 1/3 less than on-station yields (a very generous estimate in light of current yields)

- Market forces factory raw material prices down, per rescue scenarios

Table 7. Risk Analysis, Agricultural Component

Yield per harvest per ha. (MT)	Root Price ($/ MT)	Gross income per harvest per ha. ($)	Comment
22.5	$45	$1013	Per project
14.9	$45	$671	Yield 1/3 less
14.9	$35	$522	Yield 1/3 less, factory rescue scenario
14.9	$24	$358	Yield 1/3 less, factory rescue scenario

What are the rescue scenarios for agriculture? To restore farmers' income to the optimistic projections of the proposal, one has to 1) sell starch in the Bolivian market, which has prices higher than the Brazilian or export market, and 2) dedicate $90 - $150 of processing value added to farmers (equivalent to increasing root prices by $20 per MT), as payments for roots, as dividends or as rebates.

Social Aspects of the Factory Proposal

Cooperation of large numbers of farmers: The project requires that cassava roots be provided by 1,136 families, each of which plants 2 ha of cassava. Given about 35,000 farms in the Chapare, that implies that about 3% of all farmers would participate and 8% of those growing cassava currently (Table 8). The 2,272 ha. are equivalent to 36% of current planting (Table 8). These numbers are very high, especially if one were to try to achieve them as rapidly as the proposal suggests.

Further, the yields proposed in the project (22 MT/ ha.) are so far above the existing yields (6 MT/ ha. per Table 8) that we must assume that farmers would have to change their technology drastically. It is difficult to get large numbers of small-scale farmers to change technology so quickly.

The case histories for this review show that a critical issue for many cassava projects is the relationship between small-scale farmers and the processing entity. Success in the social aspects of this project is critical for its success because delays and low levels of operation affect profitability (see Risk Analysis), and because CONCADE's goal is to change behavior, specifically the crops that farmers grow.

The proposal does not provide sufficient information on producers, their attitudes towards the proposal, their actions in previous project initiatives, their current income from licit or illicit crops, seasonality of labor availability, existing organizations, behavior that might effect continuity of supplies to a plant, or other factors that would help to decide if the project is feasible.

Table 8. Farms, Area and Production of Select Crops – 1993, 1994, 1996

Item/Year	**1993**	**1994**	**1996**
Yuca (cassava)			
Farms	7,175	11,979	14,276
Hectares	3,130	5,539	6,333
Production (MT)	16,869	32,039	40,526
Rice			
Farms	5,797	7,430	12,692
Hectares	6,177	7,985	11,578
Production (MT)	8,012	10,165	14,276
Pineapple			
Farms	1,247	2,515	3,708
Hectares	665	2,362	1,952
Production (MT)	3,558	13.338*	26,567
Banana			
Farms	(NA)	5,980	5,119
Hectares	(NA)	11,690	11,604
Production (MT)	(NA)	88,560	177,178
Plantains			
Farms	(NA)	4,824	6,267
Hectares	(NA)	3,900	5,806
Production (MT)	(NA)	27,504	79,401

Source: Brown, Loyd C., "Results of the 1994 Agricultural Survey of the Tropical Zone of the Department of Cochabamba", Bolivia, Cochabamba, 1994; and INE, "Resumen Ejecutivo del III Encuesta Agropecuaria del Trópico de Cochabamba, 1996", Cochabamba, 1996. The quantity produced of pineapple was adjusted downward due to a probable error which occurred during the data processing phase of the "1994 Survey".

Evaluating the social aspects of the proposal would require fieldwork and review of existing data about the producers.

Extension: Some form of extension will be needed to get the commitment from 1,136 farmers and to train them in preparation of planting materials, new production techniques, credit management, harvest schedules, quality control, participation in ownership of the processing plant, etc. When problems arise, as they will, they will have to be explained to producers, schedules adjusted, and so forth. What training and communications methods will be used? What sort of prior agreements will be required of farmers and processor?

The project actions for extension include 1 coordinator, 3 agricultural technicians, and 3 promoters at a cost of $80,640 per year. This is a ratio of 1 technician or promoter per 187 farmers, and it is very low in Chapare conditions if these staff members are involved with promotion, technical assistance, credit management, organization (if any), assistance during harvest, etc.

Organization: Possibly, the farmers will be organized in some manner because minimal organization makes extension and credit management much more efficient.

Financing the expansion of cassava and credit: How will farmers finance their planting?

Ownership and management: The proposal is for farmers to own 20% of the factory and receive 20% of the profits. How will this be done? Will each farmer have a share? Will the participation in profits be a 'volume rebate,' as with cooperatives, or a dividend?

Competition from other crops: How attractive is cassava to farmers as a cash crop compared to cash crops? We have noted that realistic assumptions about yields and prices lower the gross value of production to levels that are unlikely to compete as monocrops with other cash crops. Still, the advantage of cassava is that it does well on acid, infertile, marginal soils where some crops, like bananas, are less likely to compete. Moreover, the low-input, low-cost production option might work in the Chapare, given the large existing areas of the crop.

Scheduling: How will transportation and harvest be organized?

Market and other fluctuations: The proposal suggests that the plant will operated at 100% of capacity, making it possible to plant just the cassava needed for processing. We doubt that his will happen. The case studies presented show that processing plants (high tech and low) have means of buffering themselves: the processor company plants some cassava, or the association buys a proportion from non-members. Farmers or non-members delay harvest or seek alternative markets when demand is weak. How would this function in this case? On the other hand, what will happen when production is low due to natural or social factors?

Alternative socio-economic models: What are the alternatives to the factory-for-export proposal? Part I of this report has shown that there are alternatives: smaller processing plants with greater farmer participation, or smaller plants owned by individuals but with less investment cost.

Indigenous lowlands peoples: The presence of indigenous lowlands peoples is a special concern and is pertinent to any proposal that involves changing land use in the project area. Two lowland indigenous groups are found in the tropical region of Cochabamba near to the roads improved by the project. These are the Yuracare and the Bia (Yuqui); both groups are in the area of direct and indirect influence of the project. Both groups have limited contact with the national culture. Several characteristics of these groups are presented in Table 9.

Table 9. Indigenous Lowland Peoples in the Area Influenced by CONCADE

	Yuracare	**Bia (Yuqui)**
Location	Rio Chapare, below Puerto Cochabamba, with some families in Puerto Aurora	Yuqui Reserve, Rio Ichilo, below 3 farms at mouth of Rio Chimore
Population	About 3000	162 (June 1997)
General production	Agricultural group; families live along the river	Recently lived as hunter-gathers; have some agriculture now
Outside presence	Government school; New Tribes Mission residences and boarding school	New Tribes Mission residences and school; several projects with government and NGOs
Land tenure	Reserve said to be in process, but not established; some conflict with Yuqui Reserve; several kolla families in the area used by Yuracare	Reserve of about 125,000 ha said to be legally established; colonos near to reserve and coming closer; logging with nominal payment to Yuqui individuals

Environmental Aspects of the Factory Proposal

Effluent

There is no effluent treatment plan. Cassava starch plants that use water to process roots produce large amounts of effluent. We estimate effluent flow as follows.

In this proposal, the plant would use 5 M3 of water per MT of roots. The roots processed per hour is estimated as: 50,000 MT of roots / 300 working days / 16 hours per day = aprox. 10 MT roots/ hour. When the roots are vacuum filtered to reduce water content more water is expelled. We would need additional information to estimate this flow exactly, but for the present we will assume that the water content is reduced from 65% to 45%. In fact, we don't know that the wet starch is at 65% moisture content (the centrifuges will have removed water and some will have gone with the fiber) going into the vacuum filter. For our purposes here (a very rough estimate), we will use this very general figure for the amount of additional water removed by the vacuum filter.

Hence,	10.21 MT * 5 M3 water	52.08 M3 effluent
	+ 20% of roots	+3.79 M3 effluent (rough estimate)
		= 56 M3 effluent per hour.

Effluent has the characteristics shown on the following table, based on Colombian tests.

Table 10. Characteristics of Cassava Processing Effluent

FACTOR	CASSAVA EFLUENT (mean value of ten varieties)	CLEAN WATER NORM
Temperature	28 deg C.	
pH	6.1	
BDO5 (Biological demand	66,000 ppm	150 ppm

for oxygen in 5 days)		
CDO (Chemical demand for oxygen)	780,000 ppm	50 ppm
Solids	72,000 ppm	< 20 ppm
Suspended solids (usually protein)	18,000 ppm	< 20 ppm
Phenols	.099 ppm	0 ppm

Source: Proton proposal-experimental work conducted at CIAT with ten cassava varieties-Unpublished document

All cassava contains naturally occurring compounds that can turn into hydrogen cyanide on processing the roots (HCN). Sweet or low-cyanide cassava has about 100 ppm of such compounds in the roots (on a fresh weight basis). Medium-levels are 250 ppm. Bitter or high cyanide varieties have 500 ppm.

If cassava processing is done slowly and at low temperature, these compounds are volatilized. At high temperatures, or in fast processing, the compounds are partially expelled with the effluent water.

Effluent treatment in starch processing plants is often carried out by leaving the water in ponds or lakes. There is little aerobic processing, perhaps because the cyanogenic compounds kill bacteria; and usually no artificial aeration is used. Eventually, the effluent evaporates and the tank is ready to be used again. The stench of such lakes is striking.

The high rainfall of the Chapare (2250 to 5000+ mm), high ground water and the substantial volume of effluent projected makes a system based on evaporation difficult (perhaps impossible) to implement. Overflow from flooded ponds into rivers is not ecologically sound, given the fact that the gravelly rivers of the Chapare are breeding grounds for migratory fish from much of the Amazon Basin. Direct effluent flow into the rivers is not acceptable.

An alternative is a treatment plant. A Colombian engineer who has designed such a plant estimates that the cost of a treatment plant is approximately equal to the cost of the processing plant.

Efficiency of Energy Usage

Elsewhere, the project figures for energy consumption are questioned. We suggest that the use of hydro-cyclones instead of or in addition to centrifuges be investigated.

Biodiversity/ Deforestation

The Tropical Zone of the Department of Cochabamba (commonly referred to as "Chapare") includes parts of the provinces of Chapare, Tiraque, and Carrasco. The zone is divided into five areas: (1) the Isiboro-Sécure National Park, (2) the Carrasco National Park, (3) the Yuqui Indigenous Reserve, (4) a temporary Forest Reservation, and (5) the Forest for Multiple Use. The Forest Reservation is a temporary designation used until the government decides what to do with an area.

Unlike the other subregions, forest for multiple use is designated for agricultural activities. Part has been provided to farmers unions (s*indicatos*) for the use of their members. About half of that area is still in woodland or forest cover. The land in the multiple use area is also subject to other legal restrictions, such as limitations on cutting trees near rivers

Geologically, the Chapare region can be divided into three main zones: the **uplands** which extend to altitudes of over 4,000 m above sea level and cover about 15% of the region; the **alluvial fans** that occur at the base of the uplands between 250 m and 200 m altitude and cover about 20% of the region; and the **lowlands** of the Amazon Basin which lie below about 200 m above sea level and cover about 65% of the region (Tolisano *et al*. 1989).

Development of the area has focused on alluvial areas because of their native fertility. To the east, there are red-brown soils (likely an ultisol) developed on a residual surface. When compared with inceptisols, these soils have lower fertility, higher aluminum saturation, and a lower pH. Such areas have been less likely to be developed.

Cassava does not tolerate flooding; but otherwise, it is very hardy and can be grown in conditions that allow few other crops (e.g. low fertility, pests, high soil aluminum, high rainfall if soils are well drained, etc.). For that reason, in a forest fallow system, it is often the planted after maize, rice, or some other, more demanding crop. It can be grown in all of the geological zones of the Chapare and in the areas of residual soils, with their lower fertility.

Therefore, in areas where land would go to bush or forest fallow, cassava's hardiness will postpone fallow or, possibly, lead to continuous cropping, and cassava will allow use of new areas. Further, if cassava development is sufficiently successful, it will lead to changed land use by increasing the incentive to shift land from primary and secondary forest (not a positive impact). We also hope that it will be so profitable that it will increase the incentive to shift from coca (a positive impact).

The effect of changing incentives would not be limited to the project directly included in the project area or road network.

Environment/ Agriculture Issues

If cassava production is intensified, especially as a monocrop, cassava pests and diseases will also become more prevalent. These include cassava hornworm (gusano cachon in Spanish, Erynnis ello). In the humid Chapare, especially with movement of planting material, we can also expect more root rot (Phytophthora and Fusarium sp.).

Control of pests and diseases using agrochemicals will then lead to additional problems. Therefore, there will be need for training and extension in management methods.

With high rainfall, there are also issues of agrochemical runoff and soil erosion.

Conclusions

The proposal for the large starch factory has some strengths: known technology, known and saleable product, raw material appropriate to the region, prices for roots projected at current levels, price for starch at Brazil levels, and an offer for private sector financing of a substantial proportion of the investment cost.

There are some unknowns: farmer acceptance, measures to handle effluents, measures to deal with high ambient humidity, modest adjustments to the equipment budget.

There are several factors in which the proposal uses the most optimistic possibilities as given: 100% utilization of capacity by Year 3; farmers providing raw material for that level of utilization by Year 3; root:starch conversion ratio of 4.0:1; starch price to root price ratio of 7.8; farmers supposed switch to monocrop production and to get experimental station yields immediately; factory risk limited to plus or minus 5% of costs and income; and agricultural risk limited to plus or minus 10% of costs and income.

Some of the assumptions are very unlikely: ability to compete with Brazil and Thailand on the world market, 'guaranteed' sales and a jump in farmer yields from 6 MT to 22.5 MT on the fields of 1,136 farmers.

The proposal does not have enough information on social and environmental factors. There are significant issues in these areas.

We think that the risks are considerably greater than those used for sensitivity analysis in the proposal. A moderately more rigorous and realistic sensitivity analysis shows plausible scenarios in which the project does not reach minimal returns, even without running worst-case scenarios.

To restore the project to even minimal economic feasibility, fixed costs have to be reduced by 30% with no loss in capacity. Alternatively, with what we consider to be modest risks, the cost of roots has to be reduced from $45/ MT to $35 or perhaps $24 per ton (the latter corresponding to current Brazilian prices in Parana State). We have suggested in the text several ways that the proposal might be modified to reduce costs. Even with these changes, the likelihood of competing on the world market is slim.

If the technical and economic aspects of the proposal are fixed, it will still require rigorous analysis from the social and ecological side, with no guarantee to passing.

As it stands, we recommend against funding implementation of the proposed starch factory.

We recommend further development of alternative proposals for lower-cost investments in cassava-based development aimed at the Bolivian domestic market. Some specific ideas are presented in the section Next Steps, below.

Following are more specific observations on the proposal.

Table 11. Feasibility Criteria for the Proposed Large Factory

AREA	FACTORS	OBSERVATIONS	SUGGESTION
Technical issues	1. General technical approach	1. The technology for starch extraction is well known, but may have to be modified for high-humidity conditions, may need to change some materials to stainless steel, and certainly needs effluent treatment.	1. Modify proposal
	2. Raw material production	2. The yields used for projections are selected from experimental research station data, and will probably be lower.	2. Hold for data and development
	3. Transformation ratio, plant utilization, ratio of starch to root prices	3. The transformation ratio of 4:1 is possible, but optimistic. The proposal uses 100% of plant capacity, very unlikely. The ratio of starch to root prices (7.8) is relatively low compared to national experiences.	3. Re-do IRR analysis more rigorously
	4. Technology/ environment relations	4. No effluent plan, a major issue for this kind of technology.	4. Correct this flaw, if possible.

AREA	FACTORS	OBSERVATIONS	SUGGESTION
Cost estimates	1. Raw material	1. Use of existing prices for projection is prudent but leads to issues of export feasibility.	1. OK
	2. Equipment and investment	2. Suggestions are made that would raise equipment price (stainless steel) and lower it (evaluate inclusion of dryers for leaves, etc.); need new estimate.	2. Adjust budget.
	3. Processing	3. Energy use likely to be higher than projected.	3. Adjust budget.
	4. Financial elements	4. Private sector financing a positive element.	4. OK
		5. Need to know Botega's current interest and source of funds.	5. Obtain information.
Markets	1. Identification of markets	1. Markets are not well identified. It is unlikely that the Chapare will compete successfully on the world commodity market. Alternative markets (Bolivia, Chile) should be explored.	1. Correct this, if possible.
	2. Price of starch	2. Projections made at prices lower than current local prices, which is prudent.	2. OK

AREA	FACTORS	OBSERVATIONS	SUGGESTION
Farmer acceptance	1. Farmer participation 2. Farmer profits	1. No information presented on farmer opinions. 2. Price of roots would have to fall to compete internationally and productivity would be less than projected on real fields, at least initially.	1. Plan and indicators of participation necessary. 2. Find out: can cassava compete?
Ecological and environ-mental issues	1. Effluent treatment or management 2. Biodiversity	1. High rainfall and humidity make the standard technology for effluents difficult in the Chapare. 2. No data provided on CONCADE or national policies re deforestation.	1. Correct, if possible. 2. Correct if possible.
Lessons learned from projects in eastern Bolivia	1. Trials of cassava drying 2. Agronomy 3. Institutional collaboration	1. Trials confirm problems with humidity. 2. Some expert resources available, but research still incipient. 3. Local university and CIAT interest in the area.	1. Take humidity into account. 2. Specify institutional support. 3. OK

Next Steps

The following steps are low-cost, preliminary steps towards a decision about cassava-based development in the Chapare.

1. Find out if Botega is still interested in the project, and if Botega could respond to the issues raised in this report.

2. Find out if Botega would be interested in participating in a smaller factory for the Bolivian market.

3. CIAT/CLAYUCA visits Chapare in January/ February, 2000. Get more information on alternative developments.

4. Find out if feed manufactures and poultry and swine producers are interested in cassava flour for animal feed, characterize the Bolivian market for starch, and check the Chilean market for starch and animal feed.

5. Discuss this report among staff members.

6. Contract or do in-house rough cost estimates and analysis for alternative cassava-based development. Include options for shifting to monocrop production and for cassava to remain a supplementary, low-cost crop. Include technology and market options identified in this report, and include single-owner and farmer-owners options.

7. Obtain preliminary field data using rapid rural appraisal techniques: farmer opinions, current prices, environmental issues, etc. Reanalyze existing survey data. Combine social science with remote sensing or GIS analisis.

8. Prepare policy responses to issues raised in this report regarding environmental and social issues.

Annexes

Annex I. Cases Histories of Cassava-based Development in Latin America

Annex II. Bibliography

ALARCÓN F., DUFOUR D. 1998. Almidón Agrio de Yuca en Colombia: Producción y Recomendaciones. Tomo 1. Cali, Colombia. CIAT, CIRAD.

CABALLERO C. Diseño de una Fábrica de Extracción de Almidón. Ministerio de Agricultura y Ganadería, MAG. *1.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1991. Proyectos Integrados de Yuca. Edit. Carlos A. Pérez-Crespo. Cali, Colombia.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1992. Cassava Breeding, Agronomy and Utilization Research in Asia. Proceedings of the Third Regional Workshop held in Malang, Indonesia, Oct. 22-27, 1990. Edit. R. H. Howeler. Bangkok, Thailand.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1994. Interfase entre los Programas de Mejoramiento, los Campos de los Agricultores y los Mercados de la Yuca en Latinoamérica. Memorias de la Tercera Reunión Panamericana de Fitomejoradores de Yuca. Documento de Trabajo Nº138. Edit. Carlos Iglesias. Cali, Colombia.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1996. A Benchmark Study on Cassava Production, Processing and Marketing in Vietnam. Proceedings of a Workshop held in Hanoi, Vietnam. Oct. 29-31, 1992. Edit. R. H. Howeler. Bangkok Thailand.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1990. Cassava Program Annual Report 1990. Working Document No. 95

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1991. Integrated Cassava Projects. Documento de Trabajo N°78. Edit. Carlos A. Pérez-Crespo. Cali, Colombia.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1992. Cassava Program 1992. Working Document No. 142

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1993. Cassava Breeding, Agronomy Research and Technology Transfer in Asia. Proceeding of the Fourth Regional Workshop held in Trivandrum, Kerala, India. Nov 2-6, 1993. Edit. R. H. Howeler. Bangkok, Thailand.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1993. Cassava Program 1993. Working Document No. 146

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1993. Cassava Program Report 1987-1989. Working Document No. 91

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT. 1995. Cassava Program 1994 and 1995. Working Document No. 168

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL. 1999. Propuesta Tecnológica Harina Integral de Yuca. Presentada por: Industrias PROTON Ltda. y Consorcio Latinoamericano y del Caribe de Apoyo a la Investigación y Desarrollo de la Yuca, CLAYUCA. Borrador 2. Palmira, Colombia.

Cock, J.H. 1984. La yuca: Una fuente básica de energía en los trópicos. Centro Internacional de Agricultura Tropical

Cock, J.H. 1989. La yuca, Nuevo potencial para un cultivo tradicional. Centro Internacional de Agricultura Tropical

Dominguez, C.E. 1982. Yuca: Investigación, Producción y Utilización. Documento de trabajo No. 50, Referencias de los cursos de capacitación sobre yuca dictados por el centro internacional de agricultura tropical

DRAGUN A., TISDELL C. Edits. 1999. Sustainable Agriculture and Environment: Globalisation and the Impact of Trade Liberalisation. Cornwall, Inglaterra.

dTp STUDIES INC. 1998. Global Cassava Market Study. Business Opportunities for the Use of Cassava. Ontario, Canada.

DUFOUR D., O'BRIEN G.M., BEST R. Edits. 1996. Cassava Flour and Starch: Progress in Research and Development. Capítulos: 5, 6, 12, 28, 29, 31, 36, 39 y 41. Cali, Colombia. CIAT Publicación #271., CIRAD.

FAO Food and Agriculture Organization - United Nations. 1992. Roots, tubers, plantains and bananas in animal feeding. Proceedings of the FAO Expert Consultation, CIAT, Cali, Colombia 21-25 January 1991. En FAO Animal Production and Health, Paper 95. Edit. David Machin, Solveig Nyvold. Roma, Italia.

GERMAN FOUNDATION FOR INTERNATIONAL DEVELOPMENT. 1996. Small-Scale Food Processing Contributing to Food Security. Proceedings of the International Workshop held from 04 to 08 September 1995 in Bonn-Röttgen, Germany. Edit. Jürgen Richter, Alois Basler, Hubertus Franzen. Eurasburg, Alemania.

GOTTRET M., HENRY G. 1997. Proyecto Integrado de Investigación y Desarrollo de la Producción y Transformación de la Yuca para la Obtención y Comercialización de Almidón Agrio de Yuca. Adopción e Impacto. Tercer Borrador. Cali, Colombia.

GOTTRET M.V., OSTERTAG C., ALONSO L., LAING D.R. 1997. Estudio de Mercado de los Diferentes Usos de la Yuca en Colombia. Informe Final-Primera Fase, Proyecto de Desarrollo de Agroempresas Rurales, presentado a: Corporación Colombia Internacional, CCI. Cali, Colombia. CIAT.

GOTTRET M.V., RAYMOND M. An Analysis of a Cassava Integrated Research and Development Approach: Has it Really Contributed to Poverty Alleviation? *2

GOTTRET V., HENRY G., DUFOUR D. 1999. Caracterización de la Agroindustria de Procesamiento de Almidón Agrio en el Departamento del Cauca. Cali, Colombia. CIAT, CIRAD.

HENRY G., GOTTRET V. 1996. Global Cassava Trends: Reassessing the Crop's Future. Documento de Trabajo Nº 157. Cali, Colombia. CIAT.

HENRY G., GOTTRET V. 1998. Client-led Agro-industrial Action Development: The Case of Cassava Starch in Cauca Valley, Colombia. Documento enviado al Simposio AFSR&E, Pretoria, Sud-Africa. Cali, Colombia.

Hernández, R. L.A. 1993. Evaluación de Nuevas Variedades de Yuca con la Participación de Agricultores. Documento de Trabajo No. 130. Centro Internacional de Agricultura Tropical

Iglesias, C.A., Fukuda, W.G. 1992. Memorias de la Segunda Reunión Panamericana de Fitomejoradores de Yuca. Documento de Trabajo No. 112. Centro Internacional de Agricultura Tropical

INSTITUTO DE INVESTIGACIONES AGRÍCOLAS “EL VALLECITO”. 1997. Caracterización Botánica de la Yuca Mainhot esculenta Crantz. Documento de Trabajo N°1. Edit. Mateo Vargas Rojas. Santa Cruz, Bolivia.

INSTITUTO DE INVESTIGACIONES AGRÍCOLAS “EL VALLECITO”. 1998. Cultivo de la Yuca. Boletín Divulgativo. Edit. Mateo Vargas. Santa Cruz, Bolivia.

INTERNET WORKSHOP, ERODE. 1999. Spac Tapioca Products India. Ltd. Manufacturers and Exporters of Tapioca Starch. http://www.spacgroup.com/

Janssen, W.G. 1986. Market Impact on Cassava’s Development Potential in the Atlantic Coast region of Colombia. Centro Internacional de Agricultura Tropical

JARAMILLO H. 1998. Almidón de Yuca. Art. en El Hombre y la Máquina, Nº13, Abril 1998. Cali, Colombia.

K.B. Helmuth, SCHOLZ W. 1971. Aspectos Industriais Da Mandioca No Nordeste. Fortaleza, Ceará. Ministério Do Interior, Banco Do Nordeste Do Brasil S.A., Departamento de Estudos Economicos do Nordeste, Divisao de Agricultura. Ceará, Brasil.

LENIS J. 1993. Comunicacao: Caracterización Morfológica y Agronómica de 27 Cultivares de Yuca en el Trópico Húmedo del Chapare, Bolivia. Chapare, Bolivia.

OFORI F., HAHN S.K. Edits. 1991. Proceedings of the Ninth Symposium of the International Society for Tropical Root Crops, held at Accra, Ghana, 20-26 October 1991. Republic of Ghana, International Society for Tropical Root Crops. Accra, Ghana.

OSTERTAG C. 1993. World Production and Marketing of Starch. Research Associate, Cassava Utilization Section. Cali, Colombia.

Reyes, J.A. 1983. Yuca: Control Integrado de Plagas. Referencias de los Cursos de Capacitación sobre Control Integrado de Plagas de la Yuca Dictados por el Centro Internacional de Agricultura Tropical

RIBEIRO E. 1987. Tecnologia de Producao de Raspas de Mandioca. Informe Agropec., Belo Horizonte, 13 145. janeiro de 1987. Río de Janeiro, Brasil.

ROIG H., SALOMON H., HERNANDEZ J., LANDI G. 1991. Proyecto Planta Piloto de Extracción de Almidón de Mandioca Manihot Esculentum. Formosa, Argentina. INTA, EEA, Técnicos de la Agencia de Extensión Rural Formosa.

ROMANOFF S. 1989. Manual de Referencia para la Promoción de Asociaciones de Promotores y Procesadores de Yuca. Quito, Ecuador. FUNDAGRO, CIAT.

ROMANOFF S., RODRIGUEZ M. 1989. La Industria de la Yuca en la Costa Ecuatoriana. Memorias del II Seminario Anual sobre la Yuca en la Estación Experimental Portoviejo del INIAP, Octubre 28-31, 1986. Quito, Ecuador. CIAT, FUNDAGRO, INIAP.

ROMANOFF S., TORO G. 1986. La Yuca en la Costa Ecuatoriana y sus Perspectivas Agroindustriales. Memorias del Primer Seminario Annual sobre la

Yuca en Portoviejo, Octubre 28 a 31, 1985. Quito, Ecuador. INIAP, IICA, CIAT.
SECHREST L., STEWART M., STICKLE T. 1999. A Synthesis of Findings concerning CGIAR Case Studies on the Adoption of Technological Innovations. Consultative Group on International Agricultural Research, CGIAR. Cali, Colombia.
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION. 1983. A Factory Concept for Integrated Cassava Processing Operations: The Cassava Processing Concept. Based on the Work of D. R. Atkinson, D. J. Wholey, T. R. W. Jarman, and J. Turnbull of P-E International Operations Ltd. and Minster Agriculture Ltd., UK. Document reproduced without formal editing. *3 Lugar
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION. 1984. A Factory Concept for Integrated Cassava Processing Operations: The raw material cassava chips: Production Systems, Quality Criteria and Techno-economic Factors. Based on the work of P. B. Steghart of P-E International Operations Ltd., U.K. and Dr. D. W. Wholey of Minster Agriculture Ltd., U.K. on contract with UNIDO. Document reproduced without formal editing. *4 Lugar
WHEATLEY C., SCOTT G., BEST R., WIERSEMA S. 1995. Adding Value to Root and Tuber Crops: A Manual on Product Development. Cali, Colombia. CIAT Publicación Nº247.
WHEATLEY C., SCOTT G., BEST R., WIERSEMA S. 1997. Métodos para Agregar Valor a Raíces y Tubérculos Alimenticios: Manual para el Desarrollo de Productos. Cali, Colombia. CIAT.
Wheatley, C., Scott, G.J., Best, R., Wiersema, S. 1997. Métodos para Agregar Valor a Raíces y Tubérculos Alimenticios. Manual para el Desarrollo de Productos
Wigg, D., Foreword., Hopper, D. 1993. The Quiet revolutionaries, A look at the campaing by agricultural scientists to fight hunger